

LONG WAVELENGTH VCSEL DEVICE PROCESSING

BACKGROUND

The invention pertains to processing and fabrication of devices, and particularly to that of on-chip light sources.

5 More particularly, the invention pertains to the processing and fabrication of vertical cavity surface emitting lasers (VCSELs).

Methods for processing long wavelength VCSELs have mostly been limited to intricate, non-uniform, and most importantly, non-robust fabrication steps. Although suitable for academic
10 level research or limited samples, they are not suitable for a large volume market driven production. There is a need for such production process.

SUMMARY

15 The present invention may cover a set of manufacturable methods and layout designs for volume batch processing of long wavelength VCSELs or other laser devices.

The processing details shown in this invention cover the necessary fabrication steps to create a VCSEL device from the
20 original crystal material grown on a wafer. The VCSEL designs covered here include those applicable to the 1200 to 1800 nm wavelength range.

Proposed below are the various types of processing flows. They cover specific cases, including the air bridge or planarization processes. The coplanar contact option is included in one of the process flows. Additional options for self aligned Fetch and substrate thinning are also included. One may select a particular process flow or a combination of steps of different process flows for each or both wavelengths of interest, i.e., 1310 nm and 1550 nm, or other wavelengths as applicable.

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BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a key of symbols for certain figures.

Figures 2, 2a and 3-33 reveal a process for making a laser structure having a coplanar contact and an air bridge over a trench for the other content.

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Figures 34-53 show a process for making a laser structure having a contact bridge over a narrow trench on a planarized dielectric and a backside contact.

Figures 54-80 illustrate a process for making a laser structure having a contact bridge over a trench on a planarized spin-on material and a backside contact

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Figures 81-107 reveal a process for a laser structure having a contact air bridge over a trench and a backside contact.

Figures 108-126 show a process for making a laser structure having a contact bridge over a trench on planarized spin-on material and a backside contact.

Figures 127-145 illustrate a process for making a laser structure having a contact air bridge over a trench and a backside contact.

Figures 146-168 reveal a process for making a laser structure having a waffle pad of small oxidation trenches.

Figures 169-171 show a process for wafer thinning for a laser structure having a backside contact.

Figures 172-181 show a self-aligned (SA) Fetch process for replacing the first portion of a process of a laser structure.

Figures 182-188 reveal variants of laser structures using the various processes described and/or portions thereof.

Figures 189-190 show more dimensions applicable to the various laser structures.

DESCRIPTION

The Figures in the present description may utilize various graphic symbols to aid in disclosure of the invention. Figure 1 is a Table showing some symbols used in some of the figures.

5 The process of making a structure 10 may start with a bottom DBR (distributed Bragg reflector) mirror 12 formed on a substrate 11, as shown in Figure 2. Situated on mirror 12 may be an intra cavity contact layer 13. On layer 13 may be an active region or layer 14, with one or more quantum wells. A top DBR mirror 15
10 may be formed on active layer 14. On mirror 15 may be a one-half wavelength thick oxide layer 16 formed with plasma enhanced chemical vapor deposition (PECVD).

A relatively wide trench photo resist 17 may be formed on oxide layer 16, as in Figure 2a. A LAM etch may be applied and
15 portions of oxide layer 16 may be etched away through photo resist 17 openings 18, in view of Figure 3. An ICP (inductively coupled plasma) etch may be used through the same openings 18 to etch away mirror 16 down to active region 14, as shown in Figure 4, to make a trench 20. In Figure 5, photo resist 17 may be
20 stripped off from oxide layer 16. There may be a layer 19 in mirror 16 that has a high aluminum content. This structure may be placed in an environment of hot vapor for wet oxidation of

layer 19 in the remaining portions of mirror 15, as noted in Figure 6.

An isolation photo resist may be applied on portions of oxide layer 16 and in part of trench 20 as shown on the left side of Figure 7. An ion implant 22 may be applied at area of trench 20. A multiple level ion implant may be performed and affect portions of the structure not covered by photo resist 21. Isolation ion implant 22 may affect portions of top mirror 15 on both sides of trench 20 on the right side of Figure 8. At the bottom of that part of trench 20, ion implant 22 may affect active layer 14, contact layer 13 and may reach into a portion of bottom mirror 12 below trench 20. Photo resist 21 may be stripped as noted in Figure 9.

An about 0.5 micron thick layer of nitride 23 may be formed with PECVD on oxide layer 16 and on the sides and the bottom of trench 20, as illustrated in Figure 10. An about one micron thickness of oxide 24 may be formed on nitride layer 23 in Figure 11, using PECVD.

To form an aperture via (i.e., a hole or an opening), a photo resist 25 may be applied on portions of oxide layer 24, including those portions in trench 20, from an outer edge, or so, to a brief distance past trench 20 towards the center, but

at a certain distance from the structure center which may be about equidistant from circular trench 20. This may result in an opening 26 in photo resist 25 situated at the center of the structure, as shown in Figure 12. In Figure 13, oxide layer 24 in opening 26 may be removed with a LAM etch. This etch tends not to remove nitride layer 23. A selective etch may be used to remove the portion of the nitride layer 23 in opening 26 with a slight under cut 27, which may be optional, below oxide layer 24, as shown in Figure 14. This etch may stop at oxide layer 16 since it is selective to the nitride and during this period of etching does not affect oxide layer 16 or oxide layer 24. Photo resist 25 may be stripped from the structure, as indicated in Figure 15.

Another photo resist 28, having a pattern with an opening 29 having a shape of a closed loop or circle for a contact via, may be applied on the structure in Figure 16. A LAM etch may be applied through opening 29 to remove an exposed portion of layer oxide layer 16. This portion of oxide layer 16 is shown removed down to top mirror 15 in Figure 17. Next a buffered oxide etch may be applied, having an effect not shown. A layer 30 of AuGe/Au may be e-beam deposited on exposed surfaces of top mirror 15 and photo resist 28, as indicated in Figure 18. A

strip and liftoff may be applied to photo resist 28 along with metal layer 30 formed on the photo resist. The result is shown by Figure 19. Remaining metal layer 30 may be an electrical contact for the resulting device of the structure. Next, metal
5 layer 30 may be annealed.

In Figure 20, photo resist layer 31 portions may be applied for eventual forming of a metal air bridge over trench 20 to connect metal layer 30 or electrical contact to a terminal external to the internal confines of trench 20. Figure 21 shows
10 a layer 32 on the structure as a result of sputter deposition of TiW/Au/Ti.

In Figure 22, a photo resist layer 33 with a pattern for bond metal may be applied. Then, a BHF (buffered hydrofluoric acid) etch of Ti may be done on layer 32. The effect is not
15 shown in Figure 22. Figure 23 illustrates an electro-plating a layer 34 of Au on the structure in areas not covered by photo resist 33. Then in Figure 24, the stripping of photo resist 33 may be made from the structure. Then a BHF etch of Ti may be done. The effect is not shown in Figure 24. The Au and TiW of
20 layer 32 may be subjected to an ion mill, the removal of those exposed portions of layer 32 are apparent in Figure 25. In

Figure 26, photo resist 31 in and above trench 20 may be removed.

Figure 27 shows an application of a photo resist 35 for a planned etching of a place for a coplanar contact. A LAM etch may be effected to remove a portion of oxide layer 24, nitride layer 23 and oxide layer 16, in that order, in an area 36 not covered by photo resist 35, as illustrated in Figure 28. An ICP or wet etch (S/C) may be effected for removing a portion of top mirror 15 and active region 14 in the same area 36 not covered by photo resist 35. The absence of portions of mirror 15 and region 14 are apparent in Figure 29. Next, a wet etch may be used to do an under cut 37 (S/C) below oxide layer 16, mirror 15 and active region 14, as shown in Figure 30. An e-beam deposition of a layer 38 of AuGe/Au material may be applied to a portion of intra cavity contact layer 13. Open area 36 of photo resist 35 may permit such deposition on layer 13 and photo resist 35 may prevent layer 38 from being put on the main structure by receiving a portion of layer 38, as Figure 31 illustrates. Layer 38 on contact layer 13 may become the other electrical (coplanar) contact for the structure. Under cut 37 may prevent layer 38 from contacting top mirror 15 and active region 14 upon a deposition of the conductive material for layer

38. Photo resist 35 and layer 38 on the photo resist may be stripped and removed from the structure, as shown in Figure 32. The remaining portion of layer 38 may be regarded as contact 38. The alloy of contact 38 may be annealed which is not illustrated in Figure 32. Figure 32 shows the resulting structure of the above-described process. Figure 33 is a top view of a VCSEL structure 10 with wide trench 20 and an intra cavity.

Another process may involve dielectric planarization, no Fetch (filter etch), a thin trench and a thick pad dielectric. Figure 34 shows a basic starting structure 40 of a VCSEL having a bottom DBR mirror 12 on a substrate 11, an active region or layer 14 on mirror 12, and a top DBR mirror 15 on active layer 14. A one-half wavelength thick oxide layer 16 may be formed on mirror 15 with PECVD, as shown in Figure 34. A photo resist layer 39 with a thin trench spoke and torus pattern for etching a trench in oxide 16 and mirror 15 may be applied on oxide layer 16 as in Figure 35. Layer 39 may have an opening 41 for etching the trench. Figure 36 shows the etched oxide layer through opening 41. Trench 42 may be ICP etched down to active layer 14 through opening 41, as shown in Figure 37.

Figure 38 shows the strip and removal of photo resist layer 39. Through wet oxidization via trenches 42, an oxidizable

layer in mirror 15 may be oxidized to an extent to result in an oxidized layer 19 for a current aperture. Oxidized layers 19 are revealed in Figure 39. At this step of the process, structure 40 may be masked for an isolation implant, and have the structure impinged with ions at doses of multiple levels such as 7×10^{14} and higher, and then the mask may be removed. These steps are not shown for this process but are similar to the steps for structure 10 as shown in Figures 7-9. These implantation steps are optional.

A layer 23 of nitride of about a 0.5 micron thickness may be applied with a PECVD process on oxide layer 16 and in trenches 42 as shown in Figure 40. On nitride layer 23, about a 2.0 micron thick layer 24 of oxide may be applied with a PECVD process on nitride layer 23, as revealed in Figure 41.

A photo resist layer 43 with an opening 44 may be formed on oxide layer 24, as shown in Figure 42. The pattern of layer 43 may be for a circular aperture having a diameter similar to the isolation if it were applied, but smaller than trench 42. In Figure 43, oxide layer 24 in opening 44 may be etched down to nitride layer 23. This etch may result in a sloped sidewall to layer 24. Nitride layer 23 in opening 44 may be etched down to

one-half wave oxide layer 16, as shown in Figure 44. Then photo resist layer may be stripped off, as shown in Figure 45.

A lift-off resist plus photo resist (LOR+PR) layer 45 having a torus pattern for opening an area 46 to a metal contact may be applied on exposed layers 16 and 24, as shown in Figure 46. In area 46, oxide layer 16 may be etched down to the top of mirror 15, as in Figure 47. An ebeam deposition of an Au/Ge alloy may be formed as an n-ohmic contact 47 on the top of mirror 15 in area 46, as revealed in Figure 48. There may be a strip and liftoff of photo resist 45 and metal 47 on it, with the result shown in Figure 49.

A photo resist layer 51 may be applied on contact 47 and layer 16 inside contact 47, as shown in Figure 50. Then a layer 52 of metal such as Au/Ge alloy may be ebeam deposited on layer 24, a small portion of layer 52 where it may connect with contact 37 and on photo resist layer 51, as indicated in Figure 51. Figure 52 shows structure 40 with photo resist 51 and metal 52 on resist 51 stripped and lifted off. Contact 37 may be connected to metal 52 for an off-structure 40 electrical connection. An n-ohmic Au/Ge alloy contact 53 may be ebeam deposited on the backside of structure 40, that is, on the bottom side of substrate 11, as shown in Figure 52. Then

contact metal 37, 52 and 53 may be RTA annealed (i.e., rapid thermal anneal).

Figure 54 shows the beginning of structure 50 to which another process may be applied. It may include BCB or SOG planarization, thick pad dielectric, wide trench and no Fetch. A one-half wave thick oxide layer 16 may be deposited on mirror 15 with PECVD. A wide trench spoke and torus pattern 54 with open area 55 may be applied on layer 16, shown in Figure 55. A portion of oxide layer 16 in open area 55 may be etched down to mirror 15 as in Figure 56. Area 55 may be also ICP etched through mirror 15 down to active layer 14 thereby resulting in a wide isolation trench 56, shown in Figure 57. The bottom of trench 56 may also be some distance above or into active region 14. Figure 58 shows the stripping result of photo resist 54.

Structure 50 may be placed in an environment of wet oxidation to oxidize an oxidizable layer in mirror 15 to result in an oxidized layer 19. Layer 19 may form a current aperture in mirror 15, as shown in Figure 59. A photo resist layer 57 having a circular pattern for an isolation implant 58 may be deposited on oxide layer 16, as shown in Figure 60. An ion implant of multiple levels at 7×10^{14} and higher doses, may be applied resulting in an isolation implant 58 shown in Figure 61.

Photo resist 57 may be stripped in Figure 62. The isolation implant steps of Figures 60-62 may be optional.

As shown in Figure 63, an about 0.5 micron layer 23 may be applied to structure 50 with PECVD. On layer 23, an about 1.0+ micron thick dielectric oxide layer 24 may be applied with PECVD. One may spin on BCB (benzocyclobutene) or SOG (spin-on glass) 59 on layer 24 including filling trenches 56, as in Figure 65. Layer 59 may be planarized to the top horizontal surface of oxide layer 24, as shown in figure 66. Then planarized material 59 may be baked and hardened.

A photo resist 61 may be deposited on oxide layer 24 and material 59 with a circular-like pattern for an aperture having a diameter similar to that of isolation 58 but smaller than the trench 56 diameter. Mask 61 with an open area 62 is shown in Figure 67. Oxide layer 24 in area 62 may be etched out with a sloped sidewall. Nitride layer 23 in area 62 may be etched out with a selective to stop at the surface of oxide layer 16. These etching steps are shown in Figures 68 and 69, respectively. Figure 70 shows structure 50 with mask 61 stripped.

A mask or photo resist layer 63 with openings 64 for a metal contact with a torus pattern may be deposited on the

surfaces of oxide layers 16 and 24. A portion of oxide layer 16 in area 64 may be etched away down to the top of mirror 15, as shown in Figure 72. Figure 73 shows photo resist material 63 stripped from structure 50.

5 A photo resist (LOR+PR) 65 for a metal full aperture and bond pad pattern may be applied on portions of layers 16, 24 and 59, as shown in Figure 74. Then an n-ohmic contact 66 may be made with the beam deposition of a thick Au/Ge alloy in area 67 on mirror 15. The results of this deposition are shown in
10 Figure 75. Metal 66 on photo resist 65, and photo resist 65 may be lifted off and stripped, respectively, as in Figure 76. A mask 68 may be applied for the bond pad connection metal layer. Metal layer 69 may be applied with electrical contact to contact 66. These steps are shown in Figures 77 and 78, respectively.
15 Photo resist 68, and metal 69 on photo resist 68 may be stripped and lifted off, respectively, as revealed in Figure 79. An n-ohmic contact 71 may be ebeam deposited on the backside of substrate 11. The deposited material may be an Au/Ge alloy. The metal of structure may be annealed (i.e., RTA).

20 Another process involving the making of an air bridge, a wide trench and a thick pad dielectric but no Fetch, may begin with a one-half wavelength thick oxide layer 16 deposited with

PECVD on a mirror 15, as shown in Figure 81. A mask 72 for a wide trench spoke and torus pattern for oxide and isolation trench etching may be deposited on oxide layer 16, as revealed for structure 60 in Figure 82. A portion of oxide layer 16 in open area 73 of mask 72 may be etched down to the top of mirror 15. Area 73 may extended by an ICP etching of mirror 15 down to active region or layer 14 resulting in a trench 74. The oxide layer 16 and mirror 15 etching results are in Figures 83 and 84, respectively. In Figure 85, photo resist or mask 72 may be stripped.

Structure 60 may be immersed in an environment resulting in wet oxidation of an oxidizable layer in mirror 15 to provide a current aperture with oxidized layer 19, as shown in Figure 86.

An isolation implant may be provided for structure 60, but may be optional depending on the desired design and application of structure 60. For such implant, a mask 75 having a circular pattern may be formed on layer 16 at about the center of structure 60 in Figure 87. An ion implant may be performed from the top direction at multiple levels, such as 7×10^{14} and higher doses. An isolation implant 58 may affect structure 60 in most areas except below mask 75. The results are shown in Figure 89. In Figure 89, mask 75 may be stripped.

About a 0.5 micron thick nitride layer 23 may be applied with PECVD on structure 60 as indicated in Figure 90. On layer 23, a thick dielectric oxide layer 24 of a one micron plus thickness may be deposited via PECVD as shown in Figure 91.

5 A mask of photo resist 76 having a circular pattern, having an opening 77 with a diameter similar to the diameter of isolation 58, but smaller than the trench diameter, may be formed on structure 60, filling in trench 74 and covering a portion of oxide layer 24, as shown in Figure 92. Oxide layer
10 24 in opening 77 may be etched with a sloped sidewall. Nitride layer may be etched with another agent that is selective to stop on the original one-half wavelength oxide layer 16. These etching results are shown in Figures 93 and 94, respectively. Photo resist 76 may be stripped from structure 60, including
15 from trench 74, as indicated in Figure 95.

 A mask of photo resist 78 having a torus pattern for opening an area 79 for a metal contact may be applied as in Figure 96. In area 79, oxide layer 16 may be etched off the top of mirror 15 as in Figure 97. Then a buffered oxide etch (BOE)
20 may be performed. On the top of structure 60, layer 81 of an n-ohmic Au/Ge/Au alloy may be formed with an ebeam deposition. The deposition is illustrated in Figure 98. After that, there

may be a metal layer 81 liftoff and a photo resist 78 strip as in Figure 99.

The backside of substrate 11 may have a layer of AuGe/Au alloy ebeam deposited as an n-ohmic contact 82, illustrated in Figure 100. The metal may be RTA annealed (i.e., with rapid thermal annealing).

In Figure 101, a material 83 like a masking or photo resist is deposited to fill in trenches 76 and cover the aperture to protect it. On structure 60, to build an air bridge, a plating base material 84 of TiW/Au/Ti may be sputtered, as illustrated in Figure 102. A bond metal fill aperture and bond pad pattern (LOR+PR) mask 85 may be applied as in Figure 103. A BHF etch may be applied in the case of Ti. Then the top pf structure 60 may be electro-plated with an about 2.0+ micron thick layer 86 of Au as illustrated in Figure 104. In Figure 105, photo resist 85 may be stripped, and layer 86 on photo resist may be lifted off. A BHF etch may be applied to the Ti. In opening 87 between the ends of layers 86, the Au and TiW material of layer 84 is ion milled down to material 83, as shown in Figure 106. Photo resist material 83 may be stripped from area 87. Also stripped may be material 83 from trench 74 thereby resulting in the formation of air bridge 88, as illustrated in Figure 107.

Another process may use BCB or SOG planarization, a thin pad dielectric and a wide trench but no Fetch. This process may start with a basic laser device for building a structure 70.

The device may have a substrate 11, a bottom DBR mirror 12

5 formed in the substrate, an active region or layer 14 formed on mirror 12, and a top DBR mirror 15 formed on active layer 14.

An about one-fourth wave-length thick layer 16 of an oxide may be PECVD deposited on the top of mirror 15, as shown in Figure 108.

10 A mask or photo resist layer 91 having a pattern for a wide trench spoke and torus pattern for oxide and isolation trench etching, with open area 92, may be formed on oxide layer 16, in Figure 109. An etchant may be applied to the top of structure 70 to remove a portion of oxide layer 16 in area 92, as shown in

15 Figure 110. Mirror 15 is ICP etched to just above or into active region 14 through area 92 of mask 91. In Figure 111, the etching of mirror 15 may be just up to active region 14, resulting in a wide trench 95. In Figure 112, photo resist 91 may be stripped. Structure 70 may be put into a wet oxidation

20 environment where at least one oxidizable layer 19 in mirror 15 may be oxidized resulting in an aperture for current and/or optical confinement during operation of structure 70. The

oxidized layers are shown in figure 113. A circular mask 93 for preventing ions implanting into the center aperture portion of structure 70 may be placed on layer 16, as in Figure 114. An ion implant 58, at multiple levels with 7e14 and higher doses, may be implemented in structure 70, as revealed in Figure 115. Figure 116 shows photo resist 93 stripped from the top of structure 70.

In Figure 117, another about one-fourth wave length thick oxide layer 94 may be deposited on oxide layer 16. BCB or SOG material 96 may be spun on layer 94 of structure 70 where trenches 95 may be filled as in Figure 118. Then material 96 may be planarized down to the top surface of oxide layer 94 with trench 95 filled to the top level of oxide layer 94, as revealed in Figure 119. Material 96 may be baked and hardened.

As Figure 120, a photo resist 97 having a mask pattern having an inside diameter about that of implant 58, to open an area 98 for metal contact may be applied on layer 94 and planarized material 96. An etch may be applied to remove about one-half wavelength of oxide, i.e., layers 16 and 94, down to the top of mirror 15 in area 98, as shown in Figure 121. Then photo resist 97 may be removed as in Figure 122.

A photo resist mask 99 for a design of a metal bridge, a full aperture and bond pad pattern (LOR+PR) may be formed on the top of mirror 15 as shown in Figure 123. A thick n-ohmic contact layer 100 of an Au/Ge alloy may be ebeam deposited on layer 94, material 96, top of mirror 15 and mask 99 as in Figure 124. Figure 125 shows the liftoff of metal 100 on photo resist 99 and the strip of photo resist 99. On the backside of substrate 11 of structure 70, an n-ohmic contact 101 may be ebeam deposited as in Figure 126.

Another process may involve an air bridge, a thin pad dielectric, a wide trench and no Fetch. Figure 127 shows the basic structure 80 of a laser device, having a substrate 11, bottom mirror 12, active region or layer 14 and top mirror 15, which may have an about one-fourth wavelength thick oxide layer 16 formed on the top of mirror 15. A mask 102, having a pattern for wide trench spoke and torus pattern for the oxide and trench etching, may be placed on layer 16 in Figure 128. Oxide layer 16 may be etched off the top of mirror 15 in open area 103 of mask 102. In Figure 130, mirror 15 may be ICP etched in area 103 down to active region 14. Alternatively, the etch may stop before layer 14 or go beyond layer 14 in mirror 12. The result

may be a trench 105. Photo resist 102 may be stripped as in Figure 131.

Structure 80 may be placed in an environment for a specific period of time to oxidize one or more oxidizable layers 19 in mirror 15 to form an aperture for current confinement when structure 80 is operating. Oxidized layer 19 is shown in Figure 132. A mask or photo resist 104 having a circular pattern may be situated over the aperture area of mirror 15 for an isolation implant, as indicated in Figure 133. An ion implant may be effected into structure 80 from the top resulting in an isolation implant 58, as shown in Figure 134. After the ion implant, photo resist 104 may be stripped as in Figure 135.

An oxide layer 106 of about one-fourth thickness may be formed on oxide layer 16 as indicated in Figure 136. Oxide layer 106 may also be formed on the surfaces of trench 105. A mask 107 having an open area 108 with a torus pattern for a contact may be applied on top of oxide layer 106 as in Figure 137. An etchant may be applied through open area 108 to etch out layers 16 and 106 down to the top surface of mirror 15, as shown in Figure 138. The total thickness of oxide etched may be about one-half of a wavelength. Then photo resist 107 may be stripped in Figure 139.

A photo resist 109 or an LOR+PR, or the like, may be spun on structure 80 as a thin layer on the surface of oxide layer 106 and the exposed top surface of mirror 15 but filling in trenches 105, as shown in Figure 140. An air bridge pattern may be developed out of layer 109 leaving the fill of material 106 in trenches 105 as in Figure 141. A LOR+PR material 110 may be applied for bridge metal, full aperture and bond pad pattern as in Figure 142. A thick n-ohmic contact layer 111 of an Au/Ge alloy may be ebeam deposited on structure 80, as shown in Figure 143. There may be a lift-off of metal 111 on photo resist 110 and a strip of photo resist 109 and 110 to result in a contact 111 on mirror 15 and an air bridge 111 formation over trench 105, as illustrated in Figure 144. An n-ohmic contact 112 of an Au/Ge alloy may be ebeam deposited on the backside of substrate 11, as shown in Figure 145.

Another process may make a waffle pattern for oxide etching and thick dielectric. Figure 146 shows a structure 90 that may have a bottom mirror 12 formed on a substrate 11, an active region or layer 14 formed on mirror 12, and a top mirror 15 formed on active layer 14. On the top surface of mirror 15, an oxide layer 16 of about one-half wavelength thickness may be PECVD deposited. On oxide layer 16, a mask 113 of photo resist

material for etching a waffle trench spoke, with a torus and waffle patterns for oxide and isolation trench etching. Open area 114 may be for the isolation trench and areas 115 may be for vertical trenches for oxidation purposes, as shown in figure 147. Figure 148 shows an etching of oxide layer 16 down to the top surface of mirror 15 in areas 114 and 115. An ICP etch of mirror 15 in areas 114 and 115 may result in trenches 116 and 117, as shown in figure 149. This illustration of structure 90 may involve either isolation trench 116 or oxidation trenches 117, or both trenches 116 and 117. For purposes of this illustrative example, both trenches 116 and 117 are discussed. Trenches 116 and 117 may be etched with the bottom above or into active region 14. Trench 116 may be ring-like around the device. Trenches 117 may be vertical-like, square or round holes down into mirror 15. In figure 150, photo resist material 113 may be stripped.

Structure 90 may be immersed in a very humid and hot environment sufficient to result in an appropriate amount of oxidation of at least one oxidizable layer in mirror 15. The wet oxidation through trench 116 may result in oxidized layers 118 and oxidation through trenches 117 may result in oxidized layers 119, as shown in figure 151. Figure 152 is a top view of

structure 90 at a more advanced stage of fabrication than that in figure 151. However, figure 152 shows a number of vertical trenches 117 that may go down from the top of structure 90 into mirror 15 to enable oxidization of layers 119 with wet oxidation via these trenches 119. The two middle oxidized layers 119 may form the aperture for current confinement in the laser device.

In figure 153, a mask 121 with a circular pattern may be formed on structure 90 over trenches 117 and portions of layer 16. Mask 121 may be made to reduce or prevent ion implantation going through it. An ion implant may be effected into structure 90 from the top resulting in implanted isolating regions 58 in second mirror 15 and first mirror 12, as in figure 154. Photo resist material 121 may be removed as in figure 155.

A layer 23 of nitride having a thickness of about 0.5 micron may be PECVD deposited on layer 16 and the surfaces of trenches 116 and 117, as illustrated in Figure 156. On layer 23, an oxide layer 24 of about 1.0+ microns (i.e., thick dielectric) may be PECVD deposited on nitride layer 23, as in Figure 157.

A photo resist 122 may be applied with a torus pattern similar to the isolation 58 diameter, smaller than the trench 116 diameter, and the inside pattern covering the aperture and

trench 117 areas, with open area 123, as in figure 158. In Figure 159, oxide layer 24 may be etched, and in figure 160, nitride layer 23 may be etched, through open area 123 of mask 122. Photo resist mask 122 may be stripped in figure 161.

5 Another mask 124 to open an area 125 for a metal contact may be applied to structure 90, as in figure 162. In figure 163, oxide layer 16 may be etched down to the top surface of mirror 15 in open area 125 of mask 124. Photo resist layer 124 may be stripped as noted in figure 164.

10 As shown in figure 165, a mask (LOR+PR) 126 with open area 127, for a full aperture and bond pad pattern, may be applied to structure 90. An Au/Ge alloy material 128 may be ebeam deposited to form an n-ohmic contact on the top surface of mirror 15, as illustrated in figure 166. Mask 127 may be

15 stripped and a lift off of metal 128 on mask 127 may be effected with the result in figure 167. An n-ohmic contact 129 of an Au/Ge alloy may be ebeam deposited or sputtered on the backside of substrate 11, as illustrated in Figure 168. The metal may be annealed (RTA). Further steps of fabrication may be similar to

20 one or more steps of the processes disclosed in this description.

Another process that may be associated with one of the processes disclosed here, or another process, is wafer thinning. This process may be added to the end of the processing flows of this description with their backside n-ohmic and anneal steps removed. Figure 169 shows a structure 100 that may be similar to structure 50 of figure 80, except that structure 100 may have a thicker substrate 11. Structure 100 may be mounted onto a lapping disk/carrier (not shown). In figure 170 structure 100 may be lapped ground/polished until the substrate 11 thickness is between 4 and 8 mils. Then an n-ohmic contact 131 may be formed on the backside of substrate 11 with an ebeam deposition of an Au/Ge alloy. Contact 131 may be (RTA) annealed.

A process for a self-aligned (SA) Fetch may be utilized. It may be used in lieu of the about first six steps of the processes described here. The basis of structure 110 in Figure 122 include a first DBR mirror 12 on a substrate 11, an active region or layer 14 on mirror 12, and a second DBR mirror 15 on active layer 14. A quarter-wavelength or so thick layer 16 of oxide may be PECVD deposited on mirror 15 as in figure 173. On layer 16, in figure 174, a nitride layer 23 of about a one-fourth wavelength thickness may be PECVD deposited. In figure 175, a mask 132, with an open area 133, having a pattern for an

SA (self-aligned) trench oxidation spoke, an isolation trench and a Fetch aperture ring, may be deposited on nitride layer 23. A portion of nitride layer 23 in open area 133 may be etched away, as shown in figure 176. A mode prot. may cover the Fetch aperture and ring with a photo resist. Oxide layer 16 may be etched out down to the top surface of mirror 15 in area 133 as revealed in figure 177. In figure 178, an ICP etch of mirror 15 down to just above or up to or into active region 14 in open area 133, may be effected resulting in a channel 134. Mask 132 of photo resist may be stripped as in figure 179. Structure 110 may be inserted into an environment that results in the wet oxidation of oxidizable layer or layers 19 in mirror 15, as illustrated in figure 180. For thick dielectric processes only, an oxide layer 24 of about one-half wavelength thickness may be formed on nitride layer 23 and the surfaces of trench 134, as indicated in figure 181. This process may be continued at the appropriate step of one of the other more complete processes in the present description.

Figures 182-188 reveal several configurations that may be made in accordance with one or more processes disclosed in the present description. As to configuration 120, it may have an air bridge 135 and a coplanar contact 38 arrangement with some

similarity to air bridge 34 and coplanar contact 38 of configuration 10 in figure 32. Configuration 130 of figure 183 may have similar features as those of figure 182 except there appears to be a metal area 136 at the center of the aperture of configuration 130. Configurations 140 and 150 of figures 184 and 185 may have several similarities to configuration 40 in figure 53. Configuration 150 may have a narrower configuration trench and a lip-overhang of contact 37 in contract to configuration 140.

Configuration 160 of figure 186 may have a material BCB or SOG spun on for supporting a bridging conductor 69 over the trench, similar to configuration 50 of figure 80. Configuration 170 of figure 187 and configuration 180 of figure 188 may have an air bridge with some similarity to the air bridge in configuration 80 of figure 145. A difference between configurations 170 and 180 is the removal of oxide at the center of the aperture in configuration 180.

The configurations described here may have various sets of dimensions. An illustrative set of dimensions can be shown as an example. A table of standard layout geometry provides several dimensions. The dimensions may be stated in microns. Figure 189 provides a top-down view of several dimensions.

Dimensions may be stated as diameters but may be some other type of dimension since not all dimensioned items are necessarily circular. Some of the dimensions are air oxide aperture diameter 141, an inner metal ring inside diameter (deposited) 142, a contact via inside diameter (etched) 143, an aperture via diameter (etched) 144, an air bridge release 145, and an inner metal ring outside diameter (deposited) 145, which may be indicated in one of the figures 182-188. Several other dimensions may include a trench inside diameter 151 and a trench outside diameter 152, as in figure 189. Other dimensional features may be identified from various illustrative examples of configurations described in this description.

Although the invention has been described with respect to at least one illustrative embodiment, many variations and modifications will become apparent to those skilled in the art upon reading the present specification. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.